EXHIBIT B

Tool and Manufacturing Engineers Handbook

THIRD EDITION

A Reference Work for Manufacturing Engineers

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or hardness of urethane. Since a softer grade will deflect under pressure before a harder grade, it is possible to govern the time during the stroke when a certain disk will begin to deflect and also, to some extent, the degree of deflection.

Accuracy in bulging is limited only by the accuracy of the cavity in the female die, as far as the outside of the workpiece is concerned. Accuracy of the inside is dependent on the accuracy of the die cavity as well as variations in the thickness of the blank.

Metals up to ⅛ in thick have been successfully bulged by this process. Expansion in one operation may be as much as 30 percent of the blank diameter for the more ductile metals such as copper, aluminum, soft brass, silver, and low-carbon steels.

Compression Operations

Coining, swaging, and sizing are metal-compression processes used to impart a pattern, configuration, or decoration on parts produced from flat-rolled material. Figure 15-86 illustrates the differences between coining, beading, and embossing operations. Sizing and swaging are closely related to coining.

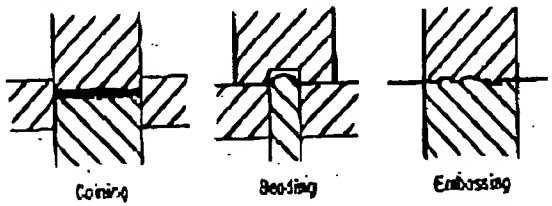

Fig. 15-86 Comparison of coining, beading, and embossing operations. *(E. W. Bliss Co.)*

Coining Coining is the most severe of the metal-squeezing operations in the amount of pressure applied to each square inch of material. In this process, the metal thickness is changed, as is the internal structure of the workpiece. Because a closed die is generally used to confine the metal, the workpiece will be an accurate reproduction of the die cavity.

Theoretically metals are not compressible, but many metals are viscous and will therefore flow under pressure. The highest pressure in a given squeezing operation is required to set the part at the very bottom of the press stroke. As movement progresses, the fluidity of the metal decreases and the pressure to sustain the movement must be increased. Both lateral and vertical movements can be achieved, and many parts that require nonuniform metal thickness can be successfully and economically manufactured only by coining.

The coining process is used to manufacture medallions, jewelry, metal buttons, and coins of all types. The process is the most practical for producing smooth surfaces that also include a design.

Coining Pressure. Accurately determining the pressure required for a coining operation is difficult. The factors determining pressure are (1) the area to be squeezed, (2) the resistance created within the metal (compressive strength), (3) the freedom of flow, and (4) the work hardenability of the metal. Some known allowable pressures for coining operations may be found by the nomograph in Fig. 15-87.

Unit pressures on materials during coining range from three to five times the compressive strength of the material. If the required pressure must be determined exactly, laboratory tests should be conducted using either a hydraulic press or a mechanical press equipped with a strain gage. A mechanical press of the knuckle-joint type is preferred for both testing and manufacturing coined objects. The knuckle-joint press provides a slow squeeze and dwell at the bottom of its stroke. It is recommended that the pressure obtained on tests in a hydraulic press be increased a minimum of 100 percent when a mechanical press is to be used for production of the part that was tested.

When a press is to be selected for coining production, consideration must be given to possible variations in thickness and properties of the metal to be coined. Also, in view of the accuracy of the part to be produced and the concentrated load that occurs, a liberal safety factor should be allowed over the theoretical load. A press operating at 50 percent of its capacity will produce better parts and run with less downtime than if it is subjected to maximum capacity to produce the same part. A small bed area with the ability to take a concentrated load with minimum deflection is desirable. Drop hammers are often used in the coining of tableware.

brass, bronze, and copper.

fracture during coining.

The advantages of parts produced by coining are dimensional accuracy, polished surfaces,

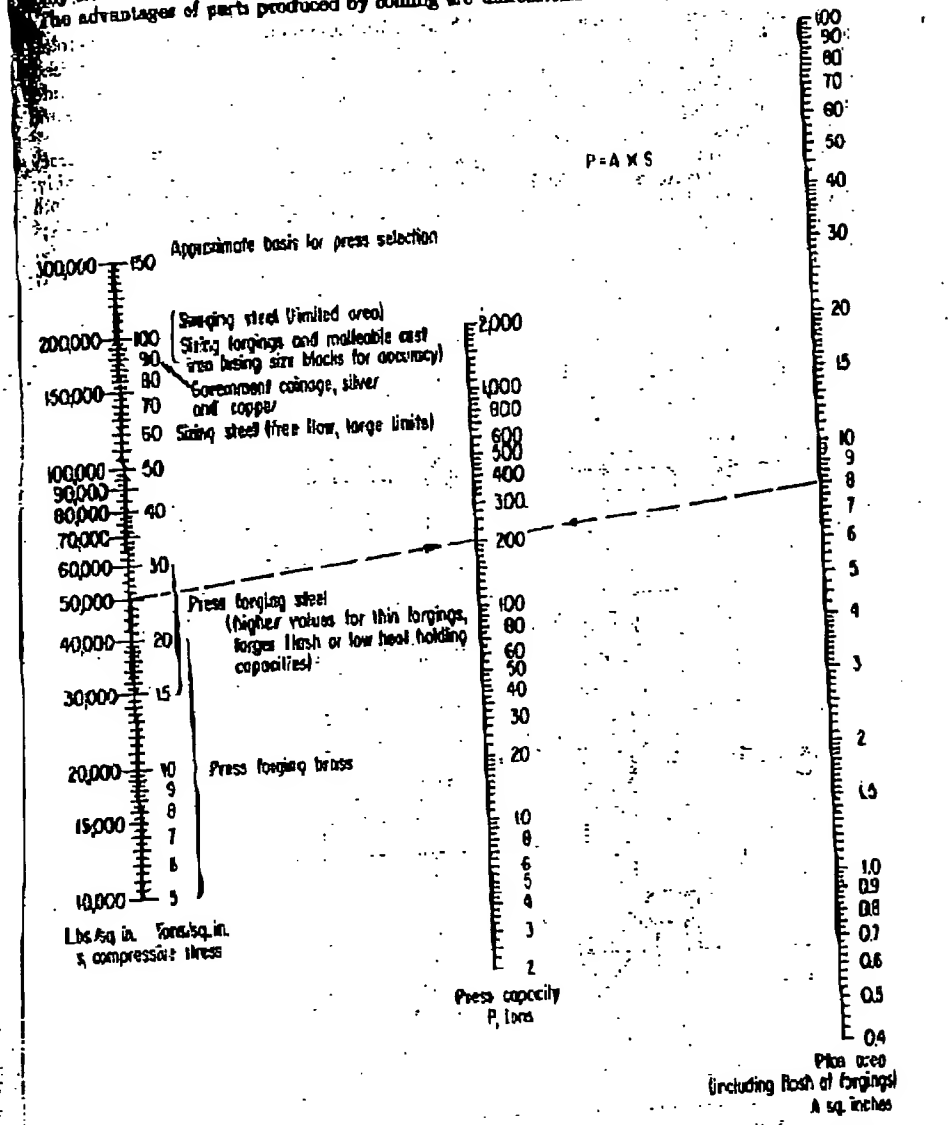

Fig. 15-87 Nomograph for estimating coining, sizing, swaging, and press-forging pressures. *(E. W. Bliss Co.)*

increased strength, and economy both in material and manufacturing. The limitations of coining processes are that die steels must be used that can withstand the high unit pressures generated and that metal movement of die components must be held to a minimum.

Sizing Sizing operations are closely related to coining in that this process, like coining, changes the metal thickness and configuration by squeezing.

Most sizing operations are performed in open dies; so the entire workpiece is not confined